FLORA W. PATTERSON.

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DOES CRONARTIUM RIBICOLA OVER-WINTER ON THE CURRANT?

F. C. STEWART AND W. H. RANKIN.

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BULLETIN No. 374.

DOES CRONARTIUM RIBICOLA OVER-WINTER ON THE CURRANT?

F. C. STEWART AND W. H. RANKIN.

SUMMARY.

Currant felt-rust and white pine blister-rust are caused by the same fungus, *Cronartium ribicola*, in different stages of its life cycle. On account of repeated outbreaks of felt-rust on currants at Geneva unaccompanied, apparently, by the occurrence of blister-rust on pines in the vicinity, it was suspected that, contrary to accepted belief, the fungus may over-winter on currants. It is important to know if this be true, because of its bearing on the control of blister-rust. If true, the distribution of affected currant plants must be prohibited; if not true, there is no necessity for such restriction.

An attempt was made to solve the problem by transplanting diseased currant plants (after the leaves had fallen) into greenhouses and forcing them into growth during the winter. Through the cooperation of four other plant pathologists it has been possible to have such tests made in six greenhouses in as many widely separated localities. In four of the greenhouses there were made, also, attempts at inoculation by means of diseased currant leaves which had been wintered out-of-doors.

Although the total number of plants used in these experiments was about 500 and every one of them had been severely attacked by the felt-rust the previous autumn, no trace of Cronartium appeared on the new leaves. This leads to the conclusion that *C. ribicola* rarely, if ever, over-winters on currants. Hence, it is unnecessary to quarantine currants affected with felt-rust.

The recent discovery of two white pine trees affected with blister-rust makes it possible, now, to account for the outbreaks of currant felt-rust at Geneva without assuming that the fungus over-winters on currants.

PROBABLE LIFE HISTORY OF THE FUNGUS.

Cronartium ribicola is an heteroecious rust fungus, parasitic on Ribes and certain species of Pinus. In its aecial stage, which is known as *Peridermium strobi* Kleb., it attacks the trunk and branches of pine trees, producing a destructive disease called blister-rust. The species of Pinus attacked are, exclusively, those which bear their leaves in fascicles of five, the principal one being *Pinus strobus*, the white pine. In its uredinial and telial stages the fungus occurs on the leaves of various species of Ribes (currants and gooseberries), both wild and cultivated. On these hosts it is known as felt-rust and is of small economic importance.

The fungus is perennial in the bark of pine trees, but the aeciospores, produced in spring, are unable to infect other pines. Hence, the fungus cannot spread from pine to pine directly. It must first go to Ribes and then back to pine. The infection of Ribes leaves by aeciospores is followed, in from 10 to 21 days, by the appearance of uredinia and, later, by telia. During the summer and autumn the teliospores germinate *in situ*, producing promycelia which bear sporidia and these are blown about by the wind and may infect the pine host but not the Ribes. The urediniospores, on the other hand, infect Ribes leaves readily so that the fungus spreads rapidly from Ribes to Ribes during the summer and autumn; but since the leaves are the only part of the Ribes plant affected and the urediniospores are short lived, the career of the fungus on Ribes closes with the falling of the leaves in autumn. That is, the fungus cannot overwinter on Ribes. Such, in brief, is the life history of *Cronartium ribicola* as it is generally understood. However, several European mycologists have noted the occurrence of *C. ribicola* in localities where the alternate host appeared to be lacking, and Eriksson, at least, has expressed the opinion that it may live from year to year on currants, entirely independent of the aecial stage on Pinus.[1]

PUZZLING OUTBREAKS AT GENEVA.

The first outbreak of the fungus in America occurred on the Station grounds at Geneva in the autumn of 1906.[2] It was quite

[1] Eriksson, Jakob. Einige Beobachtungen über den stammbewohenden Kiefernblasenrost, seine Natur und Erscheinungsweise. *Centbl. Bakt.* [etc.] II., 2:377–394. 1896.

[2] Stewart, F. C. An outbreak of the European currant rust (*Cronartium ribicola* Dietr.) N. Y. (Geneva) Sta. Tech. Bul. 2. 1906.

severe. On some of the affected black currant plants nearly every leaf was thickly covered with rust. Outside the Station grounds only a single affected leaf was found. This led to the suspicion that the outbreak originated on the Station grounds. As the few five-leaved pines in the immediate vicinity of the Station appeared healthy, attention was directed to Eriksson's theory. It was suspected that the fungus had been introduced with some Ribes plants imported by the Station from England two years earlier. Accordingly, the entire plantation was dug up and burned in an attempt to eradicate the disease.

During 1907 and 1908 no trace of Cronartium was seen. In September, 1909, after a very thorough search, a single affected leaf of red currant was found in a plantation one-half mile west of the Station. During 1910 none was found.

In August, 1911, a second outbreak occurred on the Station grounds in a currant plantation set out in 1908 and 1909. These were all native plants. A few black currant plants were attacked severely and several varieties of red currants, also, showed some infection. This time the affected plants were not destroyed and no attempt was made to determine if neighboring plantations were affected.

In the autumn of 1912 there was an epidemic of the currant rust at Geneva. It occurred on black currants in nine nurseries and ten fruit gardens. In a nursery one-half mile north of the Station almost every leaf on 15,000 black currant plants was affected. One of the affected currant plantations was located about five miles southwest, another five miles northwest and a third about two miles northeast of the Station. These were the outposts of the disease. See Map 1.

During the six years intervening between the outbreaks of 1906 and 1912 the senior author had inspected, repeatedly, many pine trees in the vicinity in an attempt to locate the source of infection. Moreover, since 1909 the nursery inspectors located at Geneva had been constantly on the lookout for diseased pines. Nevertheless, none were discovered and the origin of the outbreaks of felt-rust remained a mystery. The failure to find any affected pines becomes more significant when it is stated that the number of five-leaved pines growing in the vicinity of Geneva is small. A few miles north of Geneva there is a large natural grove of white pine, but the fact

that black currants in the immediate vicinity of this grove were free from rust is proof that the source of the infection was not to be found there.

These recurring outbreaks of felt-rust on currants, seemingly without any relation to the aecial stage on the pine, made it appear highly probable that the fungus over-winters on currants as Eriksson has suggested. This is a matter of considerable importance. If the fungus over-winters on currants the disease may be spread through the distribution of affected plants by nurserymen. Accordingly, the writers undertook to solve the problem.

Spaulding[3] having suggested that the fungus may, perhaps, overwinter by the formation of uredinia on the young shoots we first made a careful examination of the buds and bark of a large number of diseased currant plants. Although every leaf on these plants was yellow with rust no sign of uredinia or telia was found either on the buds or the bark.

GREENHOUSE EXPERIMENTS.

The next attack on the problem was by means of a series of experiments in which affected plants, after being given a short period of rest, were placed in greenhouses, forced into growth, and the new leaves watched for the appearance of Cronartium. The plants used in these experiments were yearling black currant (*Ribes nigrum*) plants from a nursery near the Experiment Station. They had been under close observation for some time prior to the falling of the leaves and it is known that every plant had been abundantly infested with Cronartium. They were dug November 19, 1912. The few leaves still clinging to them were removed. Twelve of the plants were sent to Dr. J. C. Arthur, Lafayette, Ind.; 24 to Dr. G. E. Stone, Amherst, Mass.; 50 to Dr. G. P. Clinton, New Haven, Ct.; 200 to Dr. Perley Spaulding, Washington, D. C.; 100 to the junior author at Ithaca, N. Y.; and the remaining 100 were retained by the senior author for use at Geneva, N. Y.

Under date of May 23, 1913, Dr. Arthur reports as follows concerning the plants sent him: "The plants were left out-of-doors and subject to the changes of weather until February. They were then

[3] Spaulding, Perley. The blister rust of white pine. U. S. D. A. Bur. Pl. Indus. Bul. 206:31. 1911.

put into large pots in the cool greenhouse. They started up vigorously and made most abundant and normal growth. No rust has appeared on the plants up to the present time. They were kept under constant observation and a careful study was made to determine if the plants harbored any viable urediniospores. The work regarding the spores was in charge of Mr. Edward J. Petry, an instructor in the college and an unusually careful worker. He made an examination to ascertain if urediniospores were still harbored on the currant canes. It was assumed that they might be caught in the axils of buds and branches, on the scales or the fascicled bases of the stems. Several plants were carefully washed in order to secure all the spores which were attached. Eighty cubic centimeters of water was used at each washing and this was centrifuged in eight tubes. One-half cubic centimeter of sediment was taken from the bottom of each tube and placed on several young leaves which were carefully marked. This was repeated twice at different later stages of development of the leaves. No infection has occurred up to the present time. Mr. Petry made an estimate of the number of spores placed on the leaves as follows: 'From careful quantitative counts under the microscope, $\frac{1}{2}$ c. c. at the bottom of each tube contained 100 spores, i. e., 1/40 c. c. approximately was used in each count, and ten counts were made for one tube of each washing (which had been thoroughly shaken up before centrifuging). The counts of the spores ran from 2 to 7 spores, i. e., an average of 5 spores per count was found. This would make 5 x 20 ($\frac{1}{2}$ c. c.=20/40 of 1 c. c.) or 100 spores per $\frac{1}{2}$ c. c. This $\frac{1}{2}$ c. c. (containing probably 100 spores or more) was placed on 5 leaves so that each leaf should have received 20 spores and if these spores were at all viable, infection should have taken place. Some leaves were given $\frac{1}{2}$ c. c. in different drops, but neither these nor the others showed infection. In all, about 100 leaves were tried, but none showed signs of infection. From the above data, there must have been upwards of 2,500 spores in all these centrifugings.'

"I saw quite a number of slides from this centrifuge material. The urediniospores were abundant, but I saw none which appeared to me to be certainly viable. I am inclined to think from this work that if urediniospores remain thru the winter in condition to start infection the following spring it must be under exceptional circumstances. I am inclined to think that such result does happen occa-

sionally. I do not believe that the teliospores ever have any part in carrying the infection from currant over winter to the currant again.

"While this study, as we have conducted it, has been negative and shows quite clearly that under usual circumstances the rust is not propagated from year to year by the telia or uredinia, yet it does not preclude the possibility of the rust passing by means of the urediniospores from the currant to the currant again in the following season under certain favorable conditions. It does show, I think, that the rust, at least most strains of it, are not likely to persist long unless with the intervention of the white pine."

Dr. Spaulding reports as follows:

"The 200 *Ribes nigrum* bushes were received early in the winter. They were promptly heeled in and held thus until February 1st. On this date they were transferred to the experimental greenhouse. They started off new growth promptly and very vigorously, a very fine growth being obtained. Careful examinations were made of these bushes several different times to determine whether the fungus might be present upon them. The last examination was made about the middle of May. None of the disease was found at any time upon any of these bushes. About April 1st, I separated a few of the plants from the rest and inoculated them with teleutospore material received from you at that time. There were absolutely no results from these inoculations.

"In considering the results, it must be remembered that they are entirely negative and are subject to the same limitations as are any negative results. In my opinion, these results show that the disease is not often carried over upon dormant Ribes stock. I do not believe, however, the present series of experiments can be considered to have definitely shown that the fungus may not once in a great while thus be carried over; that is, there is still left the possibility of this occurring once in a large number of cases."

Dr. Clinton makes the following report on his experiments:

"Late in the fall of 1912 I received from Stewart of the Geneva (New York) Station, a number of black currants that had been badly infected with the pine-currant rust. These were heeled in out-of-doors, and left there until the last of February when twenty-nine

PLATE I.—SHOOT OF BLACK CURRANT AFFECTED WITH FELT-RUST

The under surface of the leaves is thickly covered with the yellow, horn-like processes (telia) of the fungus.

(About two-thirds natural size.)

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PLATE II.—TRUNK OF WHITE PINE AFFECTED WITH BLISTER-RUST.

One of the two diseased trees found at Geneva in May, 1913. The light areas on the bark are partly aecia of the fungus and partly masses of exuded resin.

(About one-fourth natural size.)

PLATE III.—WHITE PINE TREE (No. 2) AFFECTED WITH BLISTER-RUST.
(About one-fourth natural size.)

were potted and placed in the greenhouse to force their foliage. About the middle of February sixteen plants were received from Stone of Amherst, these having been collected in an infected plantation in Massachusetts. These had been dug late in the fall and shipped soon afterwards, but by mistake had been sent to Storrs, so that by the time I received them they were beginning to leaf out. They were immediately placed in the greenhouse. All of these plants received from Stewart and Stone were kept in the greenhouse until late summer, examined from time to time, and no signs of the rust appeared on any of them. We still have some of them in the greenhouse at this date, January 1, 1914, but we have not seen the rust on any of these. It appears as if the rust did not carry over on this host through infections of the young perennial tissues the previous year. Certainly it does not commonly do so.

"I also received from Stewart some infected currant leaves which had been kept out-of-doors over winter, and in April I tried to infect young currant leaves from the III stage showing on these old leaves. This stage was not in good shape, indicating that its time for germination is in the fall rather than in the spring. As expected, I did not get any infection from this stage, as it is supposed to infect only the white pine."

Dr. Stone writes as follows concerning his experiments and observations in Massachusetts:

" For four or five years past the pine blister-rust has been found on imported stock in our Massachusetts nurseries, rarely if ever being found on native stock. During September, 1912, a specimen of currant rust was sent into the station from Ipswich, Mass., and this is apparently the first record of the rust in Massachusetts. At that date it was confined entirely to the black currants, variety Black Champion, of which there were four or five hundred bushes. None of the red currants were infected, and there were several acres of these growing with the black currants. One-fourth of a mile distant there was an older block of black currants which did not show the slightest infection.

"We received over three dozen infected black currant plants from Ipswich in the fall of 1912, and also two dozen from the Geneva Experiment Station. Some of each lot were transplanted directly into our greenhouse where the temperature maintained was 45° at

night. The remaining plants were heeled in out-of-doors until the first of February, when they were all transplanted beside the others.

"All the infected plants picked up very rapidly, developing good foliage, which remained green until December, 1913, or for more than one year, when most of them were taken out and thrown away. None had showed any indications of rusting during this time, and the few remaining bushes are free from rust at the present time (February, 1914). The plants which were put into the houses first without being heeled in were used in most cases for fumigation experiments.

"Careful inspection of the estate in Ipswich in 1913 showed that both the black and red currants were infected, the red currants suffering less than the others. Most of them were interplanted with apple trees and covered about thirty acres in blocks not far distant from one another. During the fall of 1912 inspection was made of the neighboring pines to see whether there was any rust, but none was noted. The past year, however, a number of pines near the infected currants have shown the rust, but this infection did not extend more than 100 yards from the currants. All of this infection is confined to imported white pines, no trace of infection being found on the native white pine. During 1913 six new locations, all in the eastern part of the state, were discovered for the currant rust, and in all thirty new pine infections. The state inspectors are doing everything possible to destroy infected material and establish a careful quarantine."

The 100 plants sent to Ithaca in the late autumn were heeled in out-of-doors until the second week of January when they were set out in benches in the greenhouse. They soon leafed out and grew vigorously. Careful observations were made for infections but none occurred. No attempt was made to inoculate the plants with wintered leaves. In May, after the finding of the two affected white pines at Geneva, inoculations were made by dusting the aeciospores from this material onto moistened Ribes leaves. The inoculated plants were covered with bell-jars and kept shaded for two days. Abundant infection resulted and the uredinia and telia were developed on almost every leaf of the 100 plants.

In the experiment at Geneva, 100 of the yearling black currant plants were placed in the greenhouse on December 2, but they did

not start into growth until about February 15. Their slowness in starting appears to have been due to their not having had a sufficiently long period of rest. However, once started, they made a vigorous, normal growth. They were kept under observation until May 7, but no Cronartium appeared upon them. Neither did any appear on the 12 black currant plants which Dr. Stone sent us from Ipswich, Mass. These latter were two-years-old plants which had been affected with Cronartium in the outbreak at Ipswich in the autumn of 1912.[4] They were planted in the greenhouse January 6, began to put out leaves January 28 and were under observation until April 17.

INOCULATION EXPERIMENTS AT GENEVA.

When it became evident that the Cronartium would not reappear, a series of inoculation experiments was undertaken with affected currant leaves wintered out-of-doors in wire cages. The previous autumn these leaves had been thickly covered with Cronartium which was mostly in the telial stage. They were brought into the laboratory, March 27, and allowed to dry. They were then ground into fine powder which was made into thin mush by stirring in a quantity of water.

Experiment No. 1.— On April 1 a quantity of the currant-leaf mush was applied to the leaves of four of the currant plants by means of a paint brush. The plants were small ones with new shoots 6 to 10 inches long and 20 to 30 leaves each. Every leaf was coated with the inoculating material on the upper surface and some, also, on the lower surface. After inoculation the plants were covered for 48 hours with bell-jars lined with moistened filter paper. During daylight the plants were shaded by covering the bell-jars with burlap. The leaves were damp all the time and during the last 24 hours most of them showed a row of water drops around the margin.

Experiment No. 2.— On April 4 four more plants were inoculated as in Experiment No. 1.

Experiment No. 3.— On April 7 four more plants were inoculated as in the preceding experiments except that the bell-jars were left over the plants for 72 hours. The leaves were still wet when the bell-jars were removed.

[4] Stone, G. E. A new rust. Mass. Sta. Rpt. 25:41. 1913.

Experiment No. 4.— On April 10 four more plants were inoculated as in experiments Nos. 1 and 2.

Experiment No. 5.— On April 10 four potted plants were placed in a large glass inoculation-chamber and their leaves smeared with currant-leaf mush as in previous experiments. The air in the chamber was kept almost constantly at the point of saturation. Drops of water appeared on the margins of the leaves as in the bell-jar experiments. On April 16 these plants were reinoculated and kept moist for three days longer.

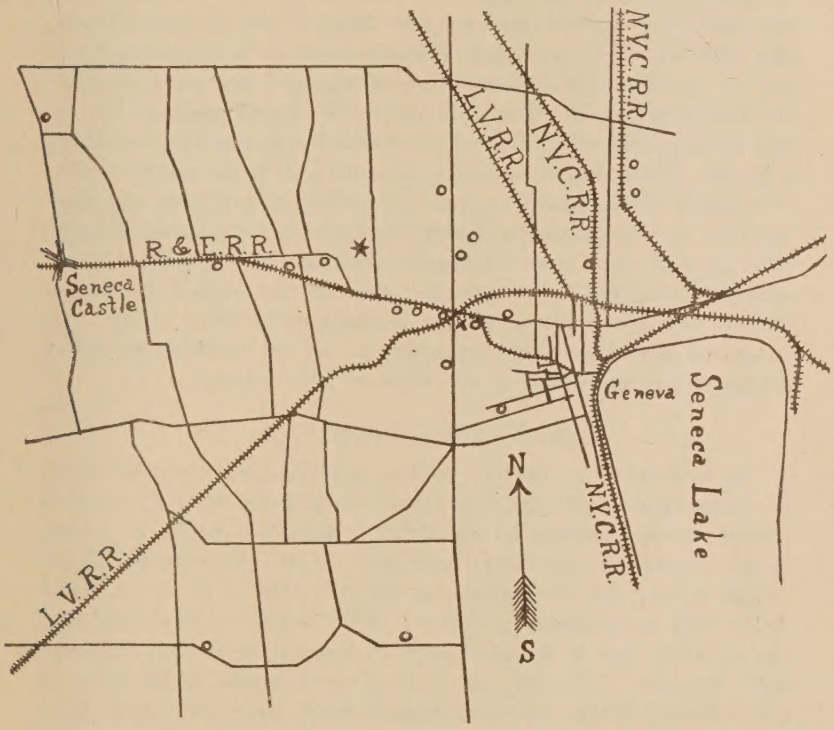
Up to May 7 no sign of Cronartium had appeared on any of the plants in the above experiments.

ORIGIN OF THE OUTBREAKS DISCOVERED.

All of the experiments having given negative results the origin of the outbreaks of currant rust became more obscure than ever. There seemed now to be but one thing to do, viz., to continue the search for affected pine trees. Early in May, 1913, the State nursery inspectors set out to examine every white pine tree in the vicinity of Geneva. On May 15, one of them, Mr. John Maney, reported that on the day previous he had discovered two white pine trees affected with blister-rust. Subsequently, his identification of the disease was fully verified. The affected trees were 9 or 10 feet high and about 15 years old. They were in a nursery about one mile west and one-half mile north of the Experiment Station. One of the trees (No. 1) was fairly vigorous and appeared not very much injured by the disease. It was attacked only on the trunk near the ground. A portion of the trunk, extending from the surface of the soil to a height of about seven inches, was thickly covered over about two-thirds of its circumference with conspicuous yellow aecia of *Peridermium strobi*. The trunk at this point was but slightly, if at all, enlarged.

Tree No. 2 stood about 120 feet from Tree No. 1. It was bushy and much distorted. Over a portion of the tree the needles were much browned. About 16 inches above the ground the trunk divided into three branches. Here was the seat of the trouble. Aecia were abundant on all of the branches and on the main trunk just below the crotch. A crotch canker had formed and borers were working in the diseased wood.

The two affected trees belonged to a lot of eight culls which had been left standing while the more desirable trees in the block had been dug and sold. Probably, they were imported trees although the owner is unable to furnish definite information on this point.



Map 1.—Distribution of *Cronartium ribicola* at Geneva in 1912 and 1913.

o = Ribes infection in 1912.
* = Pine and Ribes infection in 1913.
x = Experiment Station.

Scale, one inch = two miles.

From the fact that the point of attack was on the trunk near the ground it appears probable that they had been diseased ever since they were quite small.

Although diligent search was made no other diseased pines were found. These two trees may have been responsible for all of the

currant rust which has appeared at Geneva. They were cut down and burned on May 17.

About 120 feet south of the affected pine trees there was a small currant plantation containing both red and black currants. It was thought that the fungus might not have had a chance to infect these currants. For several days prior to May 15 the weather was dry and unfavorable for infection. The forenoon of May 15 was damp, but in the afternoon it dried off and remained dry until after the trees were destroyed. Thus it appears that the forenoon of May 15 was the only time when there was a chance for the currants to become infected. Nevertheless, infection occurred. A considerable number of uredinia were observed on June 10. Although both red and black currants in this plantation became quite abundantly infested with felt-rust and none were destroyed until about September 10, at which time the black currants were dug out and burned, the fungus did not spread to other currant plantations in the vicinity. Its failure to spread was due, probably, to the dry weather prevailing during the greater part of the summer and autumn.

DISCUSSION OF RESULTS.

The writers agree with Drs. Arthur and Spaulding that the results of these experiments do not prove conclusively that *Cronartium ribicola* never over-winters on Ribes. Negative results in experiments of this kind are never conclusive. Our interpretation of the results is that such over-wintering occurs rarely, if at all, and only under very exceptional conditions. The chances of over-wintering are so small that it is unnecessary to quarantine currants affected with felt-rust. The only precaution which needs to be taken is that affected plants are not shipped until after the leaves have fallen.

It may be argued that teliospores carried on or with affected currant plants may become a source of infection for pine trees; and because of this danger the distribution of affected currants should not be permitted. The writers consider that this objection is sufficiently answered by pointing out that the countless multitudes of teliospores which have been produced in the vicinity of Geneva during the past seven years have not infected a single pine tree so far as can be determined. However, if it seems that additional evidence is required it may be said that, normally, the teliospores

germinate only during the summer and autumn of the season in which they are produced; also, owing to the fact that the teliospores are never shed, it is improbable that they are carried, to any extent, on leafless plants.

Since the discovery of the two pine trees affected with blister-rust the outbreaks of currant rust at Geneva may be satisfactorily explained without assuming that the fungus over-winters on currants. Observations made during the epidemic of 1912 convince us that, in the uredinial stage, *Cronartium ribicola* readily spreads from one black currant plantation to another over distances of one-half mile. With this in mind it is easy to understand how, under favorable weather conditions, such an epidemic as that of 1912 may have originated with a single pair of diseased pine trees.